5.4 Hazard Profiles

Requirement: §201.4(c)(2)(i): [The risk assessment shall include the following:] An overview of the type and location of all natural hazards that can affect the State, including information on previous occurrences of hazard events, as well as the probability of future events, using maps where appropriate:

The hazards selected for profiling were examined in a methodical manner based on the following three factors, with each factor considered in detail for the hazards profiled:

- History: Background information about previous occurrences of the hazard in Arizona is provided. The information in this section is drawn mainly from the database of historical hazard events in Arizona.
- Probability and Magnitude: The probability or frequency of the hazard and its magnitude. The information in this section is drawn from a combination of national sources, Arizona expertise, and the Arizona hazard event database.

The following changes were made to the hazard profiles for this update:

- "Nature" section removed and included in other sections if applicable to Arizona. We discovered that much of this section included a very elementary definition of the hazards. Because our selected hazards are for the most part, a common occurrence in Arizona, we felt that this level of definition was not necessary.
- "History" section changed to reflect primarily the history of the hazard in Arizona as opposed to other area and/or states. We discovered that these sections included considerable nationwide accounts of the hazard occurrences. This change was made to ensure better focus on Arizona.
- "Probability & Magnitude" section was changed using the same logic as the two sections mentioned above. Again, we discovered information that was either so elementary or too detailed that it was rendered useless. However, for the following hazards the Calculated Priority Risk Index (CPRI) was used to indicate a level of probability and predictability: Drought, Earthquake, Fissure, Hazardous Materials Incidents, Landslide/Mudslide, Monsoon, Subsidence, Thunderstorms/High Winds and Wildfires. See next page for the CPRI tool.
- "Warning Time" section was removed due to the information not being specific enough for each hazard. We will revisit this section during our plan upgrade to determine how helpful the research and inclusion of this information will be to our Plan.
- "Map" a brief description on how/why the maps depicting the hazards were developed, changed or left unchanged has been added.
- "Vulnerability Analysis" was combined in the Risk Assessment section as we believe it flows better as opposed to being a separate section.

To accomplish the changes above and to ensure improved accuracy and relevance, the hazard profile sections were reviewed and revised by a Planning Team member, according to area of expertise. For example, the Team Member from the State Land Department reviewed and provided recommended changes on the wildfire profile. The Team Members also provided updated profile information to also be used for the mapping included in this section.

CPRI Category	Degree of Risk			Assigned Weighting Factor
	Level ID	Description	Index Value	
Probability	Unlikely	▪ Extremely rare with no documented history of occurrences or events. ▪ Annual probability of less than 0.001.	1	45%
	Possibly	▪ Rare occurrences with at least one documented or anecdotal historic event. ▪ Annual probability that is between 0.01 and 0.001.	2	
	Likely	▪ Occasional occurrences with at least two or more documented historic events. ▪ Annual probability that is between 0.1 and 0.01.	3	
	Highly Likely	▪ Frequent events with a well documented history of occurrence. ▪ Annual probability that is greater than 0.1.	4	
Magnitude/ Severity	Negligible	▪ Negligible property damages (less than 5% of critical and non-critical facilities and infrastructure). ▪ Injuries or illnesses are treatable with first aid and there are no deaths. ▪ Negligible quality of life lost. ▪ Shut down of critical facilities for less than 24 hours.	1	30%
	Limited	▪ Slight property damages (greater than 5% and less than 25% of critical and non-critical facilities and infrastructure). ▪ Injuries or illnesses do not result in permanent disability and there are no deaths. ▪ Moderate quality of life lost. ▪ Shut down of critical facilities for more than 1 day and less than 1 week.	2	
	Critical	▪ Moderate property damages (greater than 25% and less than 50% of critical and non-critical facilities and infrastructure). ▪ Injuries or illnesses result in permanent disability and at least one death. ▪ Shut down of critical facilities for more than 1 week and less than 1 month.	3	
	Catastrophic	▪ Severe property damages (greater than 50% of critical and non-critical facilities and infrastructure). ▪ Injuries or illnesses result in permanent disability and multiple deaths. ▪ Shut down of critical facilities for more than 1 month.	4	
Warning Time	Less than 6 hrs	Self explanatory.	4	15%
	6 to 12 hrs	Self explanatory.	3	
	12 to 24 hrs	Self explanatory.	2	
	More than 24 hrs	Self explanatory.	1	
Duration	Less than 6 hrs	Self explanatory.	1	10%
	Less than 24 hrs	Self explanatory.	2	
	Less than one wk	Self explanatory.	3	
	More than one wk	Self explanatory.	4	

5.4.1 Dam Failure

History

Two dam failure disaster declarations (Presidential or Gubernatorial) and four additional undeclared dam failure events were identified in Arizona. Collectively, these events resulted in an estimated 150 fatalities. A sampling of these events is listed below:

- February 22, 1890, the most significant dam failure experienced in the State occurred in Walnut Grove. The dam failed due to overtopping and the ensuing flood caused an estimated 150 deaths and extensive destruction of property. The failure was blamed on inadequate capacity of the spillway and poor construction (ADEM, March 1998). Located 30 miles by river north of Wickenburg on the Hassayampa River, the dam was built to provide water for irrigation and gold placer mining. The rock fill structure was 110 feet high, 400 feet long, had a base width of 140 feet, a top width of 10 feet, and a spillway of 5 feet deep by 20 feet long. The lake was 2.5 miles long by .75-1 mile wide covering over 1,100 acres, and an average depth of 60 feet.
- Based upon various accounts of the Walnut Grove Dam failure, the weather at the time was rain and melting snow. The day before the breach, water in the lake rose rapidly at the rate of about one and one-half foot per hour. The spillway was enlarged to allow excess water to escape but the effort was insufficient to stop water from running over the top. A sheet of water three feet thick reportedly poured over the dam top for six hours. Between 1:00 and 2:00 am on Saturday, February 22, 1890 the dam broke and the lake drained in one to two hours. The water rushed down Box Canyon, a narrow, steep canyon in a body 80 feet high. The floodwaters reached the town of Wickenburg, 30 miles downstream in two hours, and was still in a column 40 feet high (Graham).
- September 1997, Centennial Narrows Dam in Maricopa County failed due to flooding from Hurricane Nora. This failure is significant because the single-purpose flood control dam most likely failed due to flow through transverse cracks through the dam. Major population areas in Maricopa County are protected by earthen dams experiencing similar cracking.
- October 22, 1997, a mine tailings dam owned by BHP Copper failed due to slope failure. Approximately 300,828 cubic yards of tailings and mine rock tailings were released. The tailings flow now covers approximately 40 acres (Klochko).
- April 19, 2004, a State Declaration of Emergency was declared at River Reservoir No. 3 Dam in Apache County due to concern based on observed seepage and internal erosion. The large volume of seepage and eroded embankment soil was first observed on March 30, 2004. Successively larger increases in seepage flow and eroded embankment soils reached a magnitude on April 13 that appeared to indicate an imminent failure was possible. The County Sheriff mobilized personnel to monitor the dam on a 24-hour basis to provide early warning of a dam failure and to facilitate evacuation of residents in the threatened downstream communities of South Fork, Eagar and Springerville. The reservoir was drained immediately and the dam repaired the following year.

Arizona's Dam Safety Program has existed since 1929. Prior to 1971, funding for the Program was minimal and sporadic. Legislative approval of a consistent budget since 1971 has authorized permanent staffing and the development of a comprehensive Dam Safety Program. Arizona dam safety law includes the major areas suggested by the United States Committee on Large Dams and the National Dam Safety Program Act. The Arizona Revised Statutes (A.R.S.) § 45-1201 assigns the responsibility for supervision of the safety of non-federal dams to the Director of the Arizona Department of Water Resources (ADWR). The mission of the ADWR Dam Safety Section is to maximize the protection of the public against loss of life and property by reducing the likelihood of catastrophic failure of dams within the state's jurisdiction.

Map 18

Data was obtained from ADWR and the National Inventory of Dams. The "Dam Safety Ratings" are provided in the ADWR Safety Ratings table in the hazard profile. Initially, it was discussed to only map dams regulated by the State, but in further discussion it was determined to include federally regulated dams since they also pose a hazard and risk to the public regardless of who regulates them.

Probability and Magnitude

A dam failure is an uncontrolled release of water impounded behind the dam. Dam failures may occur due to a variety of causes. As shown in the table below, the three most common causes, i.e. leakage and piping, overtopping, and spillway erosion have been responsible for 74% of historic failures.

Causes of Dam Incidents (Dam > 50 Feet High)	
Fundamental Causes	Percentage
Foundation Leakage and Piping	35
Overtopping	25
Spillway Erosion	14
Excessive Deformation	11
Sliding	10
Gate Failure	2
Faulty Construction	2
Earthquake Instability	2
Source: "Safety of Existing Dams, 1983, National Research Council	

Dams can generally be divided into two groups: (1) storage reservoirs designed to permanently impound water, and (2) single-purpose flood control structures designed to impound water for short duration of times during flood events. In Arizona, storage reservoirs are common in the higher elevations of the state while single-purpose flood control dams are prevalent in the lower elevations.

Primary Dam Failure Risks on "Sunny Days" and During Flood Events		
	"Sunny Day"	Flood Event
Storage Reservoir Dams	Leakage and Piping	Leakage & Piping, Overtopping, Spillway Erosion
Single-Purpose Flood Control Dams	Not Applicable	Leakage & Piping, Overtopping, Spillway Erosion

Typically, the dam-break floodplain is more extensive than the floodplain used for land use development purposes and few communities consider upstream dams when permitting development. The potential severity of a full or partial dam failure is influenced by two factors: the amount of water impounded, and the density, type, and value of development and infrastructure downstream.

Federal Dams on the Salt/Verde River, the Aqua Fria River, the Gila River, and the Colorado River pose a threat to large population centers within the State. For example, failure of any Bureau of Reclamation dams on the Salt/Verde River or the Aqua Fria River would cause massive flooding in Phoenix and Maricopa County. Failure of Coolidge Dam, a Bureau of Indian Affairs Dam, on the Gila River could cause massive flooding in the Winkelman and Hayden areas of Gila County; Kearny, Florence and the Gila River Indian Reservation in Pinal County; and possibly portions of Maricopa County. Failure of Painted Rock Dam, an Army Corps of Engineers dam, also on the Gila River system, could result in massive flooding of portions of Maricopa and Yuma Counties, including the City of Yuma. Failure of any or all the Bureau of Reclamation dams on the Colorado River could cause flooding, large numbers of injuries, loss of life and massive property damage in Mohave, La Paz and Yuma Counties (ADEM, March 1998).

Non-federal single-purpose flood control dams operated and maintained by the Flood Control District of Maricopa County provide flood protection to large populations in the Phoenix Metropolitan Area. Failure of any of these dams would cause serious flooding.

The following are two sources of information that provide an indication of the risk posed by specific dams in Arizona and the potential for their failure:

- ADWR Jurisdictional Dams: ADWR has jurisdiction of over 250 dams in Arizona and is responsible for the management of non-federal dams to reduce loss of life and damage to property, and conducts safety inspections of these dams.
- National Inventory of Dams (NID): FEMA's Hazards US Multi-Hazard (HAZUS-MH) includes data on dams which is based on the NID information. The HAZUS-MH / NID database contains information on approximately 77,000 dams in the 50 states and Puerto Rico, with approximately 30 characteristics for each dam, including name, owner, river, nearest city, length, height, average storage, max storage, hazard rating, Emergency Action Plan (EAP), latitude, and longitude. The NID database includes dams that meet the following criteria: it is a high or significant hazard potential class dam or, it is a low hazard potential class dam that exceeds 25 feet in height and 15 acre-feet storage, or it is a low hazard potential class dam that exceeds 50 acre-feet storage and 6 feet height. There are 328 dams in the NID database that are located in Arizona.

The NID and ADWR databases provide useful information on the potential hazard posed by dams. Each dam in the NID is assigned one of the following three hazard potential classes based on the downstream potential for loss of life and damage to property should the dam fail (listed in increasing severity): low, significant, or high. The hazard classes are determined by the anticipated consequences that may occur in the case of the failure or misoperation of the dam or related facilities. It is important to note that the hazard potential classification is an assessment of the consequences of failure, but not an evaluation of the probability of failure.

Downstream Hazard Potential Classes		
Hazard Potential Classification	Loss of Human Life	Economic, Environmental, Lifeline Losses
Low	None expected	Low and generally limited to owner
Significant	None expected	Yes
High	Probable. One or more expected	Yes (but not necessary for this classification)
Note: The hazard potential classification is an assessment of the consequences of failure, but not an evaluation of the probability of failure.		
Sources: National Inventory of Dams, ADWR		

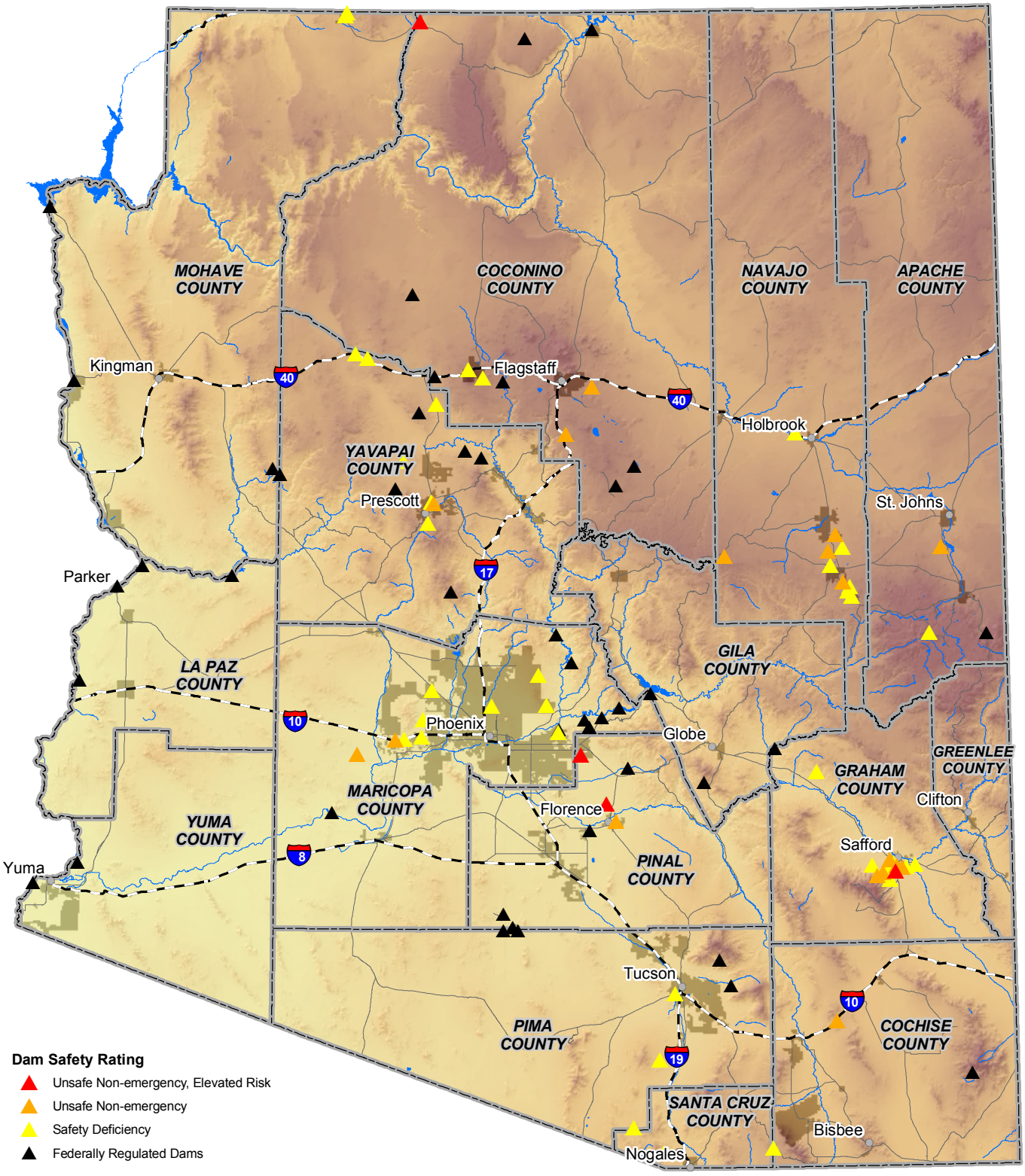
Identified Dams in Arizona, 2007				
County	High Hazard Potential	Significant Hazard Potential	Low Hazard Potential	Total
Apache	3	6	39	48
Cochise	2	3	5	10
Coconino	10	4	33	47
Gila	3	3	3	9
Graham	16	5	4	25
Greenlee	2	2	8	12
La Paz	1	0	0	1
Maricopa	43	5	10	58
Mohave	3	2	4	9
Navajo	10	4	8	22
Pima	2	6	5	13
Pinal	9	7	6	22
Santa Cruz	1	1	2	4
Yavapai	6	3	33	42
Yuma	2	1	3	6
Total	113	52	163	328
Source: NID / HAZUS-MH, ADWR July 2007				

ADWR jurisdiction dams are inspected regularly by ADWR according to downstream hazard potential classification. High hazard dams are inspected annually; significant hazard dams, every three years and low hazard dams every five years. Via these inspections, ADWR identifies safety deficiencies requiring correction and assigns each dam one of the following four safety ratings (listed in increasing severity): no deficiency, safety deficiency, unsafe non-emergency, unsafe non-emergency elevated-risk, or unsafe emergency. Examples of safety deficiencies include: Lack of an Adequate Emergency Action Plan, Inability to Safely Pass the Required Inflow Design Flood, Embankment Erosion, Dam Stability, etc.

ADWR Safety Ratings	
Safety Rating	Definition
No Deficiency	Not Applicable
Safety Deficiency	One or more conditions at the dam that impair or adversely affects the safe operation of the dam.
Unsafe Non-emergency	Safety deficiencies in a dam or spillway could result in failure of the dam with subsequent loss of human life or significant property damage. Failure is not considered imminent.
Unsafe Non-emergency Elevated Risk	Safety deficiencies in a dam or spillway could result in failure of the dam with subsequent loss of human life or significant property damage. Concern the dam could fail during a 100-yr or smaller flood.
Unsafe Emergency	The dam is in imminent risk of failure.
Source: AZ Dept of Water Resources, July 2007.	

State Regulated Dam with Identified Safety Deficiencies, 2007				
County	Safety Deficiency	Unsafe Non-emergency	Unsafe Non-emergency Elevated Risk	Unsafe Emergency
Apache	2	1	0	0
Cochise	1	1	0	0
Coconino	3	2	1	0
Gila	0	0	0	0
Graham	7	5	1	0
Greenlee	1	0	0	0
La Paz	0	0	0	0
Maricopa	8	2	0	0
Mohave	2	0	0	0
Navajo	6	4	0	0
Pima	3	0	0	0
Pinal	0	1	2	0
Santa Cruz	1	0	0	0
Yavapai	7	1	0	0
Yuma	0	0	0	0
Total	41	17	4	0
Source: AZ Dept of Water Resources, July 2007.				

State of Arizona



Note: Ratings defined in ADWR Safety Ratings table in section text.

Source: ADWR August 2007; NID 2005; URS 2003; ALRIS 2006

Legend

- Major City
- interstate
- Highway
- Major Streams
- County
- Lakes
- Cities

N

0 25 50

Miles

August 2007

State of Arizona Multi-Hazard Mitigation Plan

Map 18
State Regulated Dams with Identified Safety Deficiencies
as of 2007

JE FULLER HYDROLOGY & GEOMORPHOLOGY, INC.

Vulnerability

The estimation of potential exposure due to a dam failure was accomplished by intersecting the human and facility assets with the inundation limits in areas where data was available along the Colorado River, Navajo, Graham, Mohave and Yuma County. Since no common methodology is available for estimating losses from the exposure values, estimates of the loss-to-exposure ratios were assumed based on the perceived potential for damage. Any storm event, or series of storm events, of sufficient magnitude to cause an emergency spillway to operate or cause a dambreak scenario, would have catastrophic consequences in the inundation area. Floodwaves from these type of events generally travel very fast and possess tremendous destructive energy. Accordingly, an average loss-to-exposure ratio for the inundation areas depicted on Table 5.4.1.a is estimated at 50%. Economic losses are unavailable at this time, but it is assumed that impacted facilities will be unproductive for 60 days.

In summary, $50.28 million in asset related losses are estimated for a dam failure/inundation event. These numbers are predominantly attributed to dam failures along the Colorado River and Graham County and are subject to the accuracy of the inundation limits. More information should be made available for the next update regarding inundation areas which would result in much larger estimated losses. As a collective exposure evaluation, the loss estimates seem reasonable for event(s) of this magnitude. Regarding human vulnerability, a total population of 138,831 people, or 2.36% of the total state population, is potentially exposed to a dam failure or emergency spillway inundation event (Table 5.4.1.c). The potential for deaths and injuries are directly related to the warning time and type of event. Dam failures are usually very sudden and very destructive. Given the proximities of the dams to the impacted populations, it is anticipated that moderate warning times of 2 to 3 hours are expected. However, given the magnitude of such an event(s), it is realistic to anticipate at least one death and several injuries. There is also a high probability of population displacement for most of the inhabitants within the inundation limits downstream of a dam.

For the local risk assessment summary, Table 5.4.1.b combines asset and predominantly HAZUS information for the estimated losses as reflected in local plans. The potential total number of facilities in the inundation areas is 283,714 at a replacement cost of $54 billion. The estimated losses for dam inundations are approximately $3.3 billion.

Table 5.4.1.a: Summary of State-Owned asset inventory loss estimates based on Dam Inundations (High)

Jurisdiction	Impacted Facilities		Estimated (x $1,000)		
	Total	Percentages	Replacement Cost	Structure Loss	Total Loss
Statewide Totals	127	100.00%	$100,561	$50,280	$50,280
Apache*	0	0.00%	$0	$0	$0
Cochise*	0	0.00%	$0	$0	$0
Coconino*	0	0.00%	$0	$0	$0
Gila*	0	0.00%	$0	$0	$0
Graham	34	26.77%	$14,577	$7,289	$7,289
Greenlee*	0	0.00%	$0	$0	$0
La Paz	21	16.54%	$22,171	$11,086	$11,086
Maricopa*	0	0.00%	$0	$0	$0
Mohave	2	1.57%	$291	$146	$146
Navajo	0	0.00%	$0	$0	$0
Pima	0	0.00%	$0	$0	$0
Pinal	0	0.00%	$0	$0	$0
Santa Cruz*	0	0.00%	$0	$0	$0
Yavapai*	0	0.00%	$0	$0	$0
Yuma	70	55.12%	$63,521	$31,761	$31,761

* Denotes lack of available information for assessment.

Ranking of Most Vulnerable Communities - Dam Inundation	
County	Community
Pinal	Coolidge
Pinal	Florence
Pinal	Kearny
Maricopa	Tempe
Maricopa	Mesa
Maricopa	Phoenix
Maricopa	Scottsdale
Maricopa	Peoria
Maricopa	Fountain Hills
Maricopa	Litchfield Park

Table 5.4.1.b: Summary of Local Risk Assessment & loss estimates based on Dam Inundation			
	Total Assets $ (Assets +HAZUS) x $1,000	# of Facilities Impacted (Assets + HAZUS)	Estimated Loss (Assets +HAZUS)
Inundation			
Statewide Totals	$6,015,353	23,033	$2,766,500,000
Apache	-----	-----	-----
Cochise	-----	-----	-----
Coconino	-----	-----	-----
Gila	-----	-----	-----
Graham	$727,249	3,007	$363,700,000
Greenlee	$36,314	85	$15,300,000
La Paz	$562,096	5,118	-----
Maricopa	$47,510,104	256,471	-----
Mohave	-----	-----	-----
Navajo	$1,888,548	1,434	$985,500,000
Pima	-----	-----	-----
Pinal	$2,801,146	13,389	$1,402,000,000
Santa Cruz	-----	-----	-----
Yavapai	-----	-----	-----
Yuma	-----	-----	-----
----- Denotes lack of available information for assessment.			

State Facilities Located in the Dam Inundation Hazard Area by Jurisdiction						
	DES	HIS	ASLD	MIL	Parks	PofE
Lake Havasu			2			
Parker						5
Yuma	1	4		4	15	3
DES: Dept of Economic Security, HIS: historical site, ASLD: AZ State Land Dept., MIL: military, Parks: Board of Parks, PofE: Port of Entry.						

Table 5.4.1.c: County population sectors exposed to Dam Inundation									
	Population			Population over 65 yrs of age			Population under 18 yrs of age		
Jurisdiction	Total	Exposed	Percentage Exposed	Total	Exposed	Percentage Exposed	Total	Exposed	Percentage Exposed
High Inundation Hazard									
State-Wide Totals	5,881,719	138,831	2.36%	667,760	17,171	2.57%	1,366,714	39,645	2.90%
Apache	66,601	0	0.00%	5,741	0	0.00%	26,722	0	0.00%
Cochise	125,933	0	0.00%	17,359	0	0.00%	30,985	0	0.00%
Coconino	123,505	0	0.00%	8,150	0	0.00%	33,424	0	0.00%
Gila	51,822	1,099	2.12%	10,154	71	0.70%	12,881	451	3.50%
Graham	34,520	18,902	54.76%	3,995	3,057	76.54%	10,102	5,554	54.98%
Greenlee	7,803	0	0.00%	840	0	0.00%	2,693	0	0.00%
La Paz	19,383	3,488	18.00%	5,085	325	6.39%	4,156	1,227	29.52%
Maricopa	3,601,880	0	0.00%	358,963	0	0.00%	827,999	0	0.00%
Mohave	181,965	34,774	19.11%	31,702	6,036	19.04%	35,823	7,117	19.87%
Navajo	102,877	2,500	2.43%	9,757	321	3.29%	34,523	826	2.39%
Pima	934,680	0	0.00%	119,489	0	0.00%	207,895	0	0.00%
Pinal	216,255	0	0.00%	29,182	0	0.00%	45,085	0	0.00%
Santa Cruz	43,485	0	0.00%	4,104	0	0.00%	12,888	0	0.00%
Yavapai	192,791	0	0.00%	36,814	0	0.00%	35,402	0	0.00%
Yuma	178,218	78,068	43.80%	26,425	7,360	27.85%	46,136	24,470	53.04%

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